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Exploring the Disequilibrium in Different Fire Causes of China

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Abstract

The disequilibrium in different fire causes was analyzed by considering province, month and hour. The spatial and temporal distribution characteristic between fire causes and influence factors were investigated based on Gini coefficient and Lorenz curve, which provided a novel method and perspective to measure the disequilibrium of fire occurrence. Seven causes of fires were chosen and there existed an obvious disequilibrium between different provinces. It illustrated that playing with fire tend to keep an extreme disequilibrium both in month and hour. The high-risk factors were explored and these factors should be paid more attention. The results enhance understanding of the spatial and temporal pattern of fires and contribute to the improvement of fire prevention and management strategies.

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Keywords: fire cause, disequilibrium, Gini coefficient, spatio-temporal distribution

1. Introduction

Fires have become one of the most prominent issues of the international community. In the past several years, we continue to experience in excess of 1,000 fire-related deaths and 100,000 fire occurrences per annum in China. Especially in 2013 and 2014, the deaths rose to 2,113 and 1,817 and the fire occurrences exceeded 300,000. An extraordinary effort has been made to eliminate the potential fire risk and maintain public safety. However, the fire situation is still fairly severe in China. We need to further understand the distribution characteristic of fires and develop effective strategy of fire prevention.

There is obvious spatial and temporal distribution characteristic for fires [1-2]. It is helpful for the fire department to efficiently conduct the fire supervision management and fire prevention decision-making by identifying the fire situation of different causes of fire. The variation trends and patterns of fire show a certain law due to the different of climate, economy, and living habit [3-5]. Understanding the spatial and temporal distribution characteristic of fires, its causes and influence factors in relation to places where they occur, month and hours when they occur, is important for the implementation of efficient policies of fire prevention and fire management.

In China, the fires are divided into eleven categories: arson, electricity, disregarding safety rules, improperly using fire, smoking, playing with fire, spontaneous combustion, lightening, static, unknown, and others. There are corresponding relationships between fire causes and influence factors. Previous research has shown that playing with fires tends to be strongly associated with January and February, and the pattern is different between night and daytime [6]. By analyzing the fires of China, Yang et al found that each country has its unique characteristics of fire. They proposed that the main causes of fires are electricity, improperly using fire, smoking, and disregarding safety rules [7]. With respect to the fire situation in China, many research studies have been carried out from different views. However, a significant limitation of existing research studies on China fires is the relative paucity of studies concerned with measuring the disequilibrium of fire events.

There are several methods exist to analyze the spatial and temporal distribution characteristic of the fire occurrence. Multivariate statistics analysis methods have been widely used, such as principal component analysis, correspondence

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analysis, clustering analysis and multiple regression [8-11]. These methods mainly solve the relevancy problem. Spatial statistics are very suitable for geographic space analysis. However, it focuses on the global spatial autocorrelation and local spatial autocorrelation [12]. Gini coefficient is firstly used to measure the equality of wealth distribution. It can uncover the disequilibrium level of income among different population or areas [13]. In this study, Gini coefficients and Lorenz curve are introduced to measure the disequilibrium in different causes of fires and explore the key factors that are associated with the high incidence of fires.

The aims of the present study are to contribute to the investigation of disequilibrium in different causes of China and uncover the distribution pattern of fires that driven by the factors of province, month and hour. The main objectives are:

- Explore the patterns of disequilibrium in fire causes of China
- Identify the key factors that are associated with high risk of fire occurrence rates
- Establish an appropriate method to measure the disequilibrium in fire distribution.

2. Data and methods

2.1. Data and study factors

Fire statistics are compiled in China Fire Services by Fire Department of Ministry of Public Security.

Table 1. Contingency tables of cuases and months

2011-2013	Arson	Electricity	Disregarding safety rules	Improperly using fire	Smoking	Playing with fire	Spontaneous combustion
Jan	1280	20321	2298	11555	4172	3707	1561
Feb	1139	16920	1286	11140	4122	10700	1361
Mar	1195	16292	2364	11366	4779	2297	1615
Apr	1157	16413	2537	13008	5096	1922	1716
May	1100	16023	2262	10438	4201	1522	1589
Jun	1096	15709	1929	8867	3335	1083	1588
Jul	761	18599	2005	7788	2337	675	1940
Aug	816	18089	2024	7571	2393	815	2019
Sep	912	14493	2179	7404	2311	734	1636
Oct	1159	16229	2488	9916	3332	1333	1673
Nov	1028	14780	2292	8854	3267	997	1388
Dec	1330	18733	2415	10714	3464	1215	1604

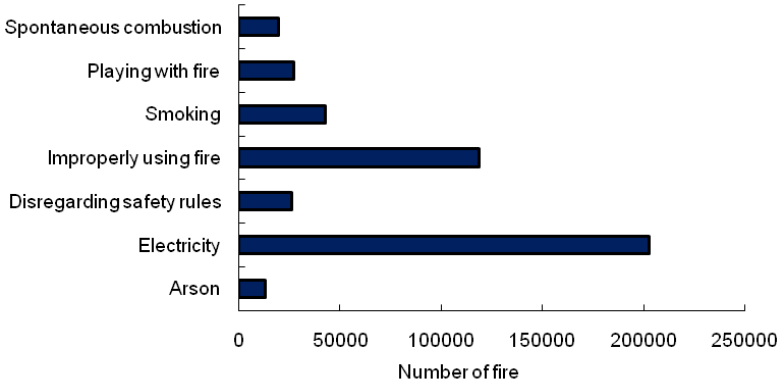

Fig. 1. The number of different causes of fires in 2011-2013

There are eleven causes in China Fire Service. Considering the problem of data size and practical significance, only seven causes of fires and three influence factors (province, month and hour) are chosen. In order to reflect the latest situation, the recent three years data are considered. Fig. 1 shows the fire occurrence rate during the period of 2011-2013.

Among the seven causes, electricity and improperly using fire contribute 71.4% to the total fires. In the following analysis, the seven causes will be measured in turn to capture the disequilibrium in the factors of province, hour and month. The 24 hours are divided into 12 groups with an interval of two hours. The data of study factors are shown in Table 1 and Table 2.

Table 2. Contingency tables of cuases and hours

2011-2013	Arson	Electricity	Disregarding safety rules	Improperly using fire	Smoking	Playing with fire	Spontaneous combustion
00～02	1347	12742	1255	5331	2327	1796	1170
02～04	1242	10534	1133	3884	1560	426	1044
04～06	774	9370	1105	3501	1180	350	890
06～08	525	11158	1361	5186	1397	501	1059
08～10	741	17004	2799	10002	2773	1197	1480
10～12	1105	20141	3481	14702	4285	2370	1934
12～14	1146	19458	2884	14684	5101	3452	2065
14～16	1299	21200	3653	15422	5987	4242	2399
16～18	1167	21293	3138	14458	5156	3733	2102
18～20	1136	23073	2158	13659	5126	3939	2144
20～22	1230	20885	1755	10567	4595	3118	1969
22～24	1261	15743	1357	7225	3322	1876	1434

2.2. Methods

Gini coefficient and Lorenz curve have been discussed in detail by many scholars [14-15]. Lorenz curve is shown in Fig 2. The absolute equality curve denotes an absolute equality of fire occurrence rate for different factors. Before drawing the curve, the data will firstly be processed and sorted from least to most according to the fire occurrence rates of different factors. Once the Lorenz curve is established, we can calculate the Gini coefficient and explore the key factors that with high risk o fires. The shadow area of A is Gini coefficient, which is also equal to A/(A+B). To obtain the shadow area, the Gini coefficient can be calculated by the integral formula.

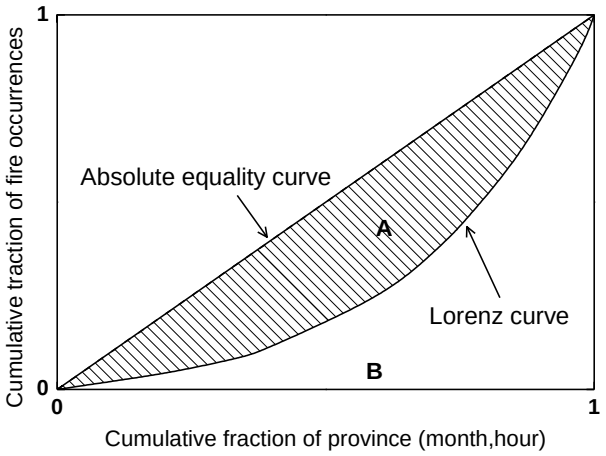

Fig. 2. Gini coefficient and Lorenz curve

Generally, Lorenz curve is composed of discrete points. In order to simplify the calculation, it will be solved as following:

where P_i is the ratio between on factor and the total number of factors, F_i is the percentage of fire occurrence in the ith factor, and Ci is the cumulative percentage of fire occurrence. A Gini coefficient of 0 indicates perfect equilibrium, and 1 indicates absolute disequilibrium. Especially, Gini coefficient of 0.4 is the warning line of extreme disequilibrium [16]. Gini coefficient can quantitatively reflect the difference degree of fire distribution. Therefore, it can effectively explore the critical value of polarization and overcome the disadvantages of other methods.

$$G = 1 - 2\int_0^1 L dx \tag{1}$$

$$Gini = \sum_{i=1}^{n} P_i F_i + 2\sum_{i=1}^{n-1} P_i (1 - C_i) - 1 \tag{2}$$

3. Results and discussion

3.1. Disequilibrium in province

Fig. 3 illustrates the spatial disequilibrium in different fire causes during 2011-2013 in China. All the values of Gini are more than 0.3, meaning a significant disequilibrium of different fire causes in the thirty-one provinces. Among seven fire causes, the most disequilibrium is spontaneous combustion with the highest Gini value of 0.438. The results also indicate that the fires show on obvious phenomenon of aggregation in space. The thirty-one provinces are arranged in the Lorenz curve according to the fire occurrence rate from least to most. The top five provinces with the highest fire occurrence rate of spontaneous combustion are Zhejiang, Jiangsu, Guangdong, Shandong and Liaoning, accounting for 39.2% of the total fires. It is observed that these provinces are developed eastern provinces. From the point of fire place, most of the spontaneous fires are caused by vehicles. The vehicle fires contribute 48.7% of the total spontaneous fires and much higher than the other 33 kinds of fire places. The transportation in Zhejiang, Jiangsu, Guangdong, Shandong and Liaoning is perfect and the number of car ownership in these provinces is far more than others. Therefore, the disequilibrium in spontaneous combustion may be related with the economics and the number of vehicles.

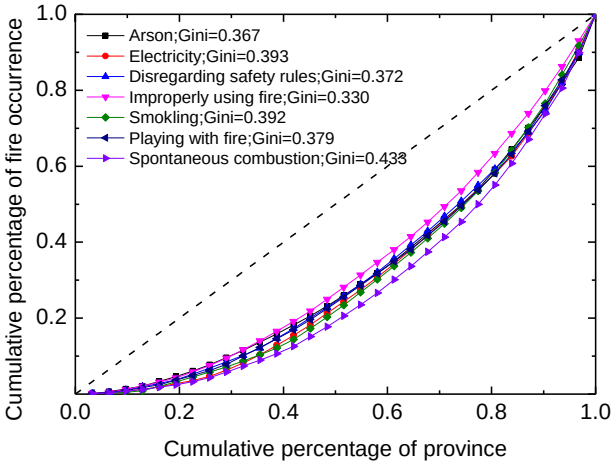

Fig. 3. Gini coefficient and Lorenz curve of province

Electricity, takes 45.1% of the total fires of seven causes, has the second highest Gini value of 0.393 and presents a significant disequilibrium. On the one hand, the overall risk of electrical fire is rather high in China and it contributes the most fire occurrence in whichever province. Therefore, we should keep on high alert to prevent the occurrence of electrical fires. On the other hand, the high value of Gini indicates that there is also strong trend of aggregation for electrical fires. The top five provinces are Zhejiang, Jiangsu, Guangdong, Hunan and Sichuan, which account for 37.4% of the total electrical fires. Similar to electrical fires, smoking fires, with the Gini value of 0.392, also tend to aggregate in only a few provinces. The top five provinces of smoking fire is Neimenggu, Liaoning, Heilongjiang, Shandong, Hebei. All these are the Northern provinces, accounting for 35.9% of the total fires. A weak disequilibrium is also observed in other four causes of fires, which still aggregate in only a few provinces. On the basis of the analysis above, the higher the Gini coefficient is, the stronger the disequilibrium is. The spatial difference should be noted and the fire prevention and control should focus on these top provinces.

3.2. Disequilibrium in month

Fig. 4 illustrates the analysis results of month. The Lorenz curves corresponding to the clusters of Gini coefficient between 0.059-0.141 and 0.474 form two distinct groups: playing with fire and other six causes of fires. With regard to the first group, the fire occurrence rates in different months reach the degree of polarization. Instead, the second group has roughly the same proportion of fire occurrences in each month and is homogeneous distribution.

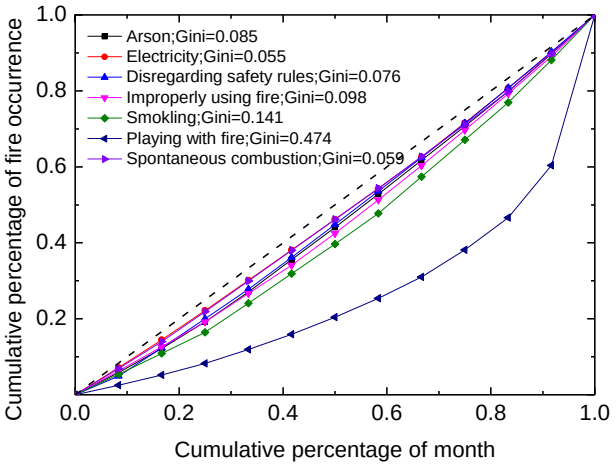

Fig. 4. Gini coefficient and Lorenz curve of month

Playing with fire shows an extreme disequilibrium. The fire occurrence tends to be aggregate in only a few months. The top three months are February, January and March, accounting for 69.0% of the total fires. The most distinguishing feature is the fact that the top five months are January, February, March, April and May and 74.6% of the total fires occur in the five months. The results indicate that the high risk of playing with fire is concentrated in the first half year or before and after the Spring Festival. The Spring Festival is the most important and grand festival in China. One of the most main customs is to set off fire crackers and fireworks, which may increase the risk of playing with fire. The results are consistent with previous research studies [6].

Smoking is considered to be slight disequilibrium. The top three months are: April, March and May, which account for 32.9% of the total fires. The Gini coefficients of spontaneous combustion, electricity and arson are less than 0.1 and the distribution of these causes is relative equal. Unlike provinces, the Gini coefficients of month show a great varying range. With regard to playing with fire, the fire department should pay more attention on February, January and March. In the three months, more fire control propaganda and fire emergency power should be made and arranged. However, there is no obvious disequilibrium in other causes, and the fire supervision and management department should not slack off at all times of year.

3.3. Disequilibrium in hour

The analysis results for hour are shown in Fig.5. It is interesting to see that the Gini coefficients cover a broad range from 0.119 (Arson) up to 0.348 (Playing with fire). The most obvious is playing with fire. The top three time intervals are 14-16, 18-20 and 16-18, with 44.1% of the total fires. Judging from the 24 hours, nearly 68.5% of the total fires of playing with fire occur in the afternoon and the first half of the night from 14 to 22 o'clock. The disequilibrium in playing with fire is notable and this should be considered when making fire prevention and control measurements.

Smoking, improperly using fire and disregarding safety rules is considered to be slight disequilibrium. The top three time intervals for the three causes are: 14-16, 16-18 and 18-20; 14-16, 10-12 and 12-14; 14-16, 10-12 and 16-18. It should be noted that 14-16 appears in the three causes simultaneously, meaning a high risk of fires during 14-16. These time intervals are mainly in working time. Therefore, both the fire department and the workers should put more focus on fire risk during the working hours to prevent the fires caused by smoking, improperly using fire or disregarding safety rules. Furthermore, we can try to warn people of the risk of smoking fire, remind the workers operating in accordance with the relevant provisions, and propagandize the matters needing attention for fire over the time period.

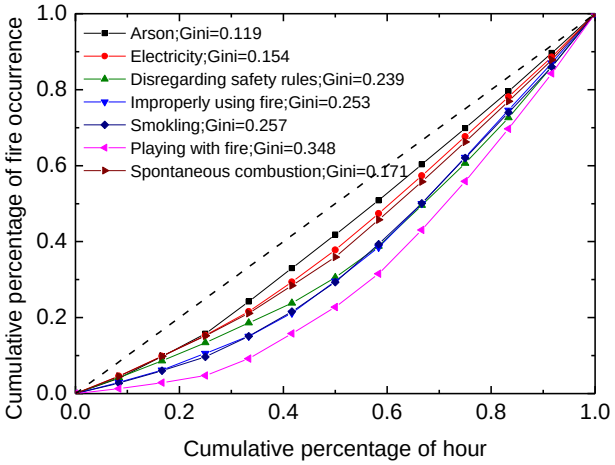

Fig. 5. Gini coefficient and Lorenz curve of hour

The Gini coefficients of the other three causes are less than 0.2. The distribution of these causes of fires in time series is relative equal. By exploring the key time intervals, the high risk period of electricity and arson is 16-20 and 00-02, respectively. One point needs to be emphasized: although the Gini coefficient of electrical fire is less than 0.2, the fire hazards of electrical fire should be checked throughout the 24 hours. We should always remember that the electrical fires account for 45.1% of the total fires from 2011 to 2013.

4. Conclusions

The purpose of this study is to provide a better understanding of the disequilibrium of fire occurrence rate by considering province, month and hour in China. It may also contribute to make up the limitations of existing research studies. The results are helpful for supervision and emergency rescue so that fire brigades can operate more efficiently based on the fire risk assessment. It demonstrates that Gini coefficient and Lorenz curve can well uncover the disequilibrium characteristics of fire risk and identify the key factors with high risk of fire occurrence rate. These findings clearly indicate that:

(1) Different causes of fires show obvious disequilibrium in the provinces. When taking a national fire deployment, the disequilibrium should be considered. Especially, these top provinces merit more attention and fire resource.

(2) There is an extreme disequilibrium distribution in playing with fire both in different month and different time intervals. These aspects need to be considered in order to help the fire brigades to choose the best strategies.

(3) The key factors with the highest risk of fire occurrence are explored and listed in Table 3.

Table 3. Top three factors with the highest risk of fire occurrence in each causes

Causes	Province	Month	Hour
Arson	Shandong, Liaoning, Guangdong	Dec, Jan, Mar	00-02, 14-16, 22-24
Electricity	Zhejiang, Jiangsu, Guangdong	Jan, Dec, Jul	18-20, 16-18, 14-16
Disregarding safety rules	Zhejiang, Jiangsu, Guangdong	Apr, Oct, Dec	14-16, 10-12, 16-18
Improperly using fire	Liaoning, Heilongjiang, Zhejiang	Apr, Jan, Mar	14-16, 10-12, 12-14
Smoking	Neimenggu, Liaoning, Heilongjiang	Apr, Mar, May	14-16, 16-18, 18-20
Playing with fire	Neimenggu, Liaoning, Ningxia	Feb, Jan, Mar	14-16, 18-20, 16-18
Spontaneous combustion	Zhejiang, Jiangsu, Guangdong	Aug, Jul, Apr	14-16, 18-20, 16-18

The study also brings significant messages to fire risk assessment. In the future, a systematical spatio-temporal analysis should be conducted in the risk analysis. The results motivated a further research for fire department in China to propose a new analytical method and improve the efficiency and scientific of operating.

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